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GUIDE FOR PROCESSING SOIL TEMPERATURE OBSERVATIONS

Foreward

The Guide for Processing Soil Temperature Observations is being published for the first time. It is the result of many years of experience gained by the Main Geophysical Observatory in processing soil temperature observations and has the purpose of making available to local administrations of the Hydrometeorological Service the uniform processing method which is in use in the Main Geophysical Observatory and which has been tested in practical work.

The Guide was compiled by workers of the climatology ~~and~~ processing group and is a collection of principles ~~which are~~ applied in the Main Geophysical Observatory. Ye. Ya. Shcherbakova and Ye. A. Andreyev served as general editors of the Guide.

Skobtsev, Deputy Chief of the Meteorological Administration

General Information

Soil temperature observations are made in accordance with the Guide by second-order meteorological stations of the Main Administration of the Hydrometeorological Service, USSR.

Soil temperature observations (notebooks and tables) received from the meteorological stations are subjected to processing through the following steps:

1. Preliminary review of notebooks and tables
2. Critical review of monthly tables
3. Checking of notebooks and monthly tables
4. Compilation and checking of annual summaries
5. Critical review of annual summaries
6. Preparation for printing

The procedural order of the first three steps is not rigidly adhered to. For instance, ~~checking of~~ notebooks and tables ~~can~~ may be ~~done~~ checked before critical review; preliminary review may be omitted if the observations are fully processed immediately upon receipt. In the latter case, preliminary review and critical review are combined.

Before processing of soil temperature observations can begin, it is necessary to have complete answers to the following questions about the thermometers being used:

1. What types of thermometers are being used: Savinov, Shukevich, or draw-out (vytyazhnyye) thermometers?

It is necessary to indicate the types of soil thermometers being used at the stations because not all types of thermometers set at identical shallow (up to 0.40-meter) depths give completely identical readings.

2. At what depth was each thermometer set?

The depth at which thermometers were set must be ascertained since in the course of time the depth may change due to settling of the soil, removal of soil, addition of soil, etc.

3. What is the control and plant number?

Knowledge of the thermometer's number is required for checking and as a precaution against substitution of thermometers at the stations. The observer often fails to report substitution.

4. Has the zero point of the thermometers been checked at the stations; if so, when and how?

Particular attention should be paid to this matter because in draw-out thermometers a shifting of the zero point may take place as a result of two causes:

a. The passage of time causes deformation of the glass of the reservoir. This deformation is brought about especially by the pressure resulting from oxidation of the copper filings and causes the zero point to rise.

b. Careless lowering of the thermometer into its tube causes the reservoir to be jarred on the bottom of the tube. This repeated jarring also causes the zero point to rise.

5. In what condition are the thermometers?

a. Is the outer glass casing intact?

b. Is the scale intact?

Defects in the outer glass casing and in the scale are the most common defects in soil thermometers. A defect in the casing can cause a shift in the scale which will raise the thermometer readings.

c. Do the thermometers fit tightly into their tubes and are they equipped with cloth collars?

If the thermometers fit loosely into their tubes and/or if cloth collars on their sticks are missing, cold outside air will enter the tubes and cause the thermometers to give lower temperature readings.

d. Is the opening in the copper case tightly sealed so that none of the copper filings have been lost; i. e., has that heat inertia, which a soil thermometer must have, remained undisturbed?

When copper filings have been lost, thermometers can change their readings at the time they are being read due to the influence of outside air. Occurrences of this nature are detected during surveys of temperatures taken at great depths, where soil temperatures often remain almost constant over a long period of time, so that a sudden small increase in the reading suggests that the copper filings may have been lost.

e. Does the base of the copper case reach down to the bottom of the tube?

If the base of the copper case does not reach down to the bottom of the tube, an air space, which is a poor conductor of heat, will be created.

f. What kind of tubes do the thermometers have - ebonite or wooden?

Since ebonite and wood have different heat conductivities, the readings of thermometers set at identical depths but in different types ~~kinds~~ of tubes will differ.

g. Has water or moisture entered the tubes?

The presence of water in the tubes retards changes in thermometer readings because of the high heat capacity of water. In addition, there is the danger that at shallow depths where the soil freezes, the base of the copper case, or the case itself, will freeze to the bottom of the tube.

6. How high does the tube for each individual depth extend above the surface of the ground?

The height of the tubes into which the thermometers are lowered is important especially in winter when snow lies on the ground and when the depth of the snow can ~~could~~ exceed the height of the tube.

7. Is there a wooden bench?

a. How is the bench set up?

b. Is the board of the bench removed after observations have been made?

If there is no wooden bench, the observer is obliged to make his readings on the ground, thus disturbing the natural cover: the grass in summer, the snow in winter.

8. Are the tubes supported by guy wires?

When the tubes are not supported by guy wires, the tubes tend to become loose and space forms between the soil and the tubes. The space disturbs the normal transmission of heat from the surface of the soil downward and permits the inflow of water and cold air into it.

9. By what method were the thermometers set: by digging trenches and holes or by boring them?

The structure of the soil is broken ~~to a greater or lesser degree~~ when thermometers are set by ~~different~~ improper methods. Soil structure is broken less when holes are bored, if the rules set forth in the directions are observed.

10. Do the thermometers stand in the shade? If so, what shades them and at what time?

11. In what condition is the surface of the soil during the summer?

a. Is it covered with vegetation? If so, what kind and how high is it?

b. If the grass is being mowed, is this fact indicated?

Vegetation has an effect not only on the temperature of the surface of the soil but also on the temperature of deeper soil layers. The effect will vary with the height of vegetation. Mowing of grass immediately affects the temperature near the surface. Vegetation reduces soil temperature during the summer.

c. Is the vegetation characteristic of the surrounding area?

12. In what condition is the surface of the soil during the winter?

a. Is it covered with snow or has the snow been cleared away?

b. Are observations being made of the depth of the snow by means of a special depth gauge placed near the thermometers?

To calculate the effect of a certain depth of snow on soil temperatures, it is necessary to measure the depth of the snow at the place where the temperature observations are being made and nowhere else.

13. Was a description of the soil profile prepared at the time ~~when~~ the thermometers were set?

14. In what kind of soil was each thermometer set (clay loam, clay, sand, chernozem, etc.)?

Warming up of the soil as well as heat transmission downward depend~~s~~ on the physical properties of the soil, especially its heat capacity and its heat conductivity. For this reason, the station must supply a soil profile together with a description of ~~the~~ the composition of the soil.

15. Is the composition of the soil where the thermometers were set characteristic of the surrounding area?

16. How high does ground water stand?

Since moisture changes the warmth of the soil considerably, it is important to know whether ground water reaches up to any thermometer.

17. When were the thermometers set at their respective places? If a substitution of thermometers was made, what was the exact time when the change was made?

I. Preliminary Review of Notebooks and Tables

The object of the preliminary review is to make a preliminary evaluation of the material received and to take steps to correct any omissions and deviations from the Guide for Second-order Meteorological Stations (Fifth Edition) made by the observer.

The person making the preliminary review must be well acquainted with the Guide and must know equally well the location of the station whose ~~the~~ work ~~of which~~ he is reviewing.

Deficiencies in observation data which require immediate correction are: incomplete information about the soil thermometers (~~what kinds, their~~ types numbers, etc.), gaps in observations, missing nowhere else.

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Deficiencies in observation data which require immediate correction are: incomplete information about the soil thermometers (~~what kinds, their~~ types numbers, etc.), gaps in observations, missing minus signs for readings below zero, clerical errors, erasures, vague and obscure notations, instances where 0.0 is shown and obviously is an error, etc.

Instructions are forwarded to the observer to take immediate steps to correct and clarify all deficiencies discovered during the preliminary review.

II. Critical Review of Monthly Tables

When beginning the critical review of daily soil temperature observations, it is necessary to have not only all the information about the station and its equipment indicated above, but also tables of basic observations in regard to general weather conditions.

In addition, it is very useful to have the soil temperature observations of the nearest neighboring stations, especially if the stations are similar ~~as~~ in regard to physical and geographical conditions to the station, whose ~~the~~ materials ~~of which~~ are being processed.

Critical review of soil temperature observations is carried out by comparing soil temperature changes in adjacent layers, ~~and~~ ~~also~~ by reviewing air temperatures and temperatures at the surface of the soil, and by noting ~~Attention is paid to~~ other weather conditions, especially to cloudiness and hydrometeors.

If soil temperature observations of neighboring stations are available, temperature changes for ~~at~~ a given depth are compared with changes for ~~at~~ the same depth at neighboring stations.

Soil temperature changes in general follow changes in air temperature. [Footnote states that this statement must be understood conditionally].

Critical review of daily soil temperature observations is begun with a review of ~~the~~ average monthly soil temperatures . This involves comparing the averages for given depths with those for other depths and with those for corresponding depths at neighboring stations. It is easiest to start the review with the greatest depth since the temperature changes very slowly there. ~~Already~~ at a depth ~~greater~~ of more than one meter the sharp daily variation in air temperature and changes in weather are not reflected immediately in soil temperature changes.

It is more difficult to make the critical review of daily soil temperatures for shallower depths since all weather changes are quickly reflected there.

Average monthly soil temperatures for various depths calculated from observations made at the Ufa station in 1928 are shown in Table 1.

Stevenson Screen [Air Temperature]	Months	Depths (meters)				
		0.20	0.40	0.80	1.60	3.20
- 13.6	January	- 1.2	- 0.6	0.9	3.4	6.1
- 13.1	February	- 1.1	- 0.5	0.7	2.8	5.3
- 11.4	March	- 1.5	- 0.8	0.4	2.3	4.7
1.1	April	0.1	- 0.2	0.4	1.9	4.2
12.4	May	7.2	5.9	4.1	3.0	3.9
16.3	June	12.2	11.8	9.9	6.9	4.7
18.8	July	16.2	15.1	13.1	9.6	6.0
16.6	August	15.5	15.0	14.1	11.3	7.8
12.0	September	12.3	12.3	12.3	11.1	8.1
3.5	October	5.7	6.6	8.2	9.2	8.3
- 3.0	November	2.2	3.2	4.9	6.7	7.7
- 10.8	December	- 3.5	- 1.6	1.4	4.6	7.0
	Year	5.4	5.5	5.9	6.1	6.1

Table 1. Average Monthly Soil Temperatures, Ufa Station, 1928

It is apparent from Table 1 that soil temperature follows the air temperature, ~~with some~~ somewhat lagging behind. Thus, while the air temperature from February to March rose somewhat, soil temperatures for all observed depths dropped during the same period, and for the 3.20-meter depth the drop continued into May. Similarly, while the average monthly air temperature reached its maximum in July, the maximum average soil temperature for the 3.20-meter depth was observed in October.

Average monthly temperatures observed in 1928 at the Ufa station are shown graphically in Figure 1.

It is evident from the graph that when the thermometers operate properly and observations are made correctly, all curves corresponding to the various depths are located above each other in a definite sequence, in direct or converse order of depth depending on the season of the year.

Also clearly evident from the graph is the reduced annual temperature fluctuation range at the deeper depths.

The highest points of the curves, which correspond with the highest average monthly temperatures, shift with the depth towards the latter months of the year. This shift indicates that soils warm up more slowly at the greater depths, although the rate of warming up depends on the heat capacity and heat conductivity of the soils.

Influence of Natural Cover on Soil Temperature

The influence of natural (vegetative or snow) cover on the variation in average monthly and average annual soil temperatures can be seen from the observations made at the Poltava station in 1916 (Table 2). Observations were made simultaneously at corresponding depths on two different areas: one area was waste land with natural cover, the other was fallow land with bare but loose soil.

Months	Waste Land (Depths, meters) 0.10	0.25	0.50	1.00	1.50	2.00	Fallow (Depths, meters) 0.10	0.25	0.50	1.00	1.50	2.00
January	-	- 1.5	0.1	2.4	4.2	5.9	- 3.5	- 2.0	- 0.5	1.7	3.9	5.6
February	-	- 0.9	- 0.1	1.6	3.1	4.6	- 1.7	- 0.8	- 0.3	1.1	2.9	4.4
March	0.2	- 0.2	- 0.2	1.1	2.2	3.4	0.6	0.2	- 0.2	0.9	2.4	3.8
April	7.3	6.3	5.2	3.6	3.1	3.3	7.6	6.6	5.6	4.4	3.9	4.2
May	13.8	12.9	11.5	8.8	7.0	6.1	14.3	13.4	11.9	9.7	7.8	6.8
June	18.4	17.0	15.4	12.4	10.2	8.9	19.3	18.1	16.3	13.7	11.2	9.5
July	20.6	19.0	17.7	14.9	12.8	11.3	21.6	20.6	18.9	16.5	14.0	12.1
August	19.0	18.3	17.5	15.8	14.3	13.0	19.2	19.0	18.3	17.1	15.4	13.7
September	13.6	13.8	14.5	14.5	14.0	13.3	14.0	14.5	15.1	15.3	14.8	13.9
October	8.4	8.9	9.9	11.1	11.6	11.9	8.0	8.7	9.7	11.0	11.9	12.3
November	2.2	3.1	4.7	7.2	8.8	9.9	1.7	2.7	4.2	6.4	8.6	9.8
December	-0.8	0.2	1.8	4.3	6.1	7.5	- 1.6	0.0	1.3	3.4	5.6	7.4
Year	-	8.1	8.2	8.1	8.1	8.3	8.3	8.4	8.4	8.4	8.5	8.6

Table 2. Average Monthly and Average Annual Soil Temperatures, Poltava, 1916

This example shows that all temperature changes are much sharper in bare soil than in soil with natural cover. The changes would have been even sharper if the bare soil had not been loose, since loosening reduces heat conductivity. Yet, it is clearly shown that bare soil has lower temperatures in winter and higher temperatures in summer than soil with cover.

Effect of a Shift in the Thermometer Scale

The most frequent defect in draw-out soil thermometers, but a defect which is easily detected during review of average monthly temperatures, is a shift in the thermometer scale. Observations made at the Velikiy Ustyug station in 1929 (Table 3) ~~can~~ may serve as an example to show how it is possible to detect this defect when reviewing average monthly and average annual soil temperatures.

Months	Depths (meters)			
	0.15	0.40	0.50	0.80
January	-	- 0.9	1.5	0.4
February	-	- 2.3	- 0.1	0.1
March	-	- 2.0	0.3	- 0.3
April	-	- 1.2	0.3	- 0.3
May	-	3.3	5.1	0.7
June	13.1	11.7	14.3	8.4
July	16.8	15.6	17.8	12.9
August	15.5	15.4	18.3	14.1
September	8.9	10.0	13.1	10.7
October	4.7	5.8	8.9	6.9
November	1.5	2.8	5.9	4.2
December	-	0.3	3.6	1.8
Year	-	4.9	7.4	5.0

Table 3. Average Monthly and Average Annual Soil Temperatures, Velikiy Ustyug Station, 1929

Looking at the average monthly temperatures for all depths, it is seen that the temperatures for the 0.50-meter depth stay above all other temperatures at almost all times.

The same fact can be seen on the graph of monthly temperatures (Figure 2 following).

During the winter, the 0.40-meter curve should be below and the 0.80-meter curve above all other curves. During the summer, the converse should be true: the 0.40-meter curve should be above and the 0.80-meter curve below all other curves. In spring and fall, all curves should intersect. Actually, as seen on the graph, the 0.50-meter curve does not intersect the other curves in spring and fall. The only intersection occurs in February - in winter. Thus, it ~~is indicated~~ may be seen that all thermometer readings for the 0.50-meter depth are incorrect, that they are too high. A check of the instrument disclosed that the scale of this thermometer had shifted considerably downward, a fact which explains the high readings. Observations made with such a thermometer must be rejected.

The observations made at the Kherson (Agricultural ~~College~~ Institute) station in 1917 (Table 4) can be used as another example for evaluating average monthly temperature observations. The station was in operation only 10 months in 1917.

Months	Depths (meters)					
	0.10	0.20	0.40	0.80	1.60	3.20
January	1.8	2.3	2.9	4.6	7.2	10.1
February	- 1.8	- 0.7	0.0	2.2	5.5	9.3
March	1.0	0.3	0.5	1.3	4.0	8.1
April	11.4	10.4	10.0	8.5	6.7	7.6
May	14.6	13.6	13.1	11.8	9.8	8.8
June	21.0	19.6	18.7	16.5	13.3	10.3
July	23.0	22.0	21.2	19.5	16.1	12.1
August	23.9	22.7	22.1	20.1	17.3	13.6
September	18.6	18.1	18.2	18.0	17.0	14.4
October	12.7	12.6	13.3	14.4	17.7	14.3
November	-	-	-	-	-	-
December	-	-	-	-	-	-

Table 4. Average Monthly Soil Temperatures, Kherson (Agricultural ~~College~~ Institute) Station, 1917

with the temperatures shown for other depths.

~~Reviewing~~ the October daily observations (Table 5) show ~~, it is seen~~ that the temperature for the 1.60-meter depth decreases evenly; but on 9 October it rises 0.2 degree, on 11 October it jumps 1.5 degrees, and on 25 October rises 0.6 degree. These readings indicate that the scale of the thermometer had become loose and slipped downward. The observer made no comment about these readings either in his notebooks or in the tables.

The observations made in October with this thermometer for the 1.60-meter depth must be rejected.

Isopleths

The distribution of average soil temperatures according to depth and ~~according to~~ time may also be represented by means of thermo-isopleths, which are very satisfactory for graphic representation since they permit immediate comprehension of the whole picture, including temperature variations as well as all defects in temperature distribution which may be present. Thermoisopleths constructed from the 1928 data of the Ufa station and the 1928 data of the Poltava station are presented as illustrations in Figure 3 and Figure 4 respectively. The observations made there were good and the thermoisopleths constructed from them exhibit an altogether normal appearance.

Depth Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Av. Annual Temp.

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Figure 3. Thermoisopleths, Ufa Station, 1928

Depths Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Av. Annual Temp.

Page 13 (bottom) in original

5.4

7.3

Correction to be made from original

8.6

Figure 4. Thermoisopleths, Poltava Station, 1928

Thermoisopleths may usefully be employed for plotting less than a full year by months and less than a full month by days.

After a review of average monthly temperatures has been completed, detailed review of the monthly observation tables, day by day and period by period, begins. It must be remembered that the warming or cooling of the surface of the soil depends to a great extent on the heat capacity and heat conductivity of the soil and that the temperature at the surface may differ considerably from the air temperature. This circumstance has an effect on the upper soil layers. Reviews of daily data should consider the temperature at the surface of the soil.

Data from the Belogorka station prepared in June 1928 (Table 6) furnishes an example of incorrect readings.

In Table 6, the incorrect readings for the 0.80 and 1.60-meter depths on 11 June stand out conspicuously. It is obvious in both cases that a 5-degree increase is erroneous since the increase for the 0.40-meter depth does not exceed one degree.

Another, but less serious error, is seen in the reading for the 1.60-meter depth on 7 June. This could, of course, have been a natural rise in temperature for this depth if there had been a great rise for the depths above it several days before. Since this is not the case, the 8.4-degree reading must be considered erroneous by about 0.3 degree.

This table makes it clear that when reviewing observations for the greater depths, it is sufficient to determine whether the temperature changes evenly from day to day. All interruptions in even variation must be scrutinized in relation to the readings for the other depths.

Observations from the Belogorka station covering the days from 20 to 27 June 1928 (Table 7) also serve to illustrate how erroneous readings for the shallower depths can easily be detected.

Date	Air Temperature					Precipitation	Weather Conditions	Soil Temperatures for Indicated Depths (m)				
								0.40			0.80	1.60
	0700	1300	2100	Max.	Min.			0700	1300	2100	1300	1300
3	8.0	13.3	6.4	14.0	5.3	-		8.8	8.8	9.4	9.0	8.1
4	9.1	13.0	10.6	13.3	- 1.4	-		9.2	9.2	9.7	8.9	8.1
5	9.0	6.8	6.2	10.7	6.1	11.6	(a) ~~●a,1,a,2,p~~	9.7	9.6	9.6	8.8	8.1
6	5.1	7.6	4.6	11.5	1.8	6.2	(b) ~~●01,2,p~~	7.9	8.9	9.4	8.9	8.1
7	4.5	6.9	5.1	7.7	2.3	0.7	(c) ~~▲1,a~~	8.1	8.9	9.5	8.7	8.4
8	6.8	11.1	8.7	13.2	- 1.2	-		8.6	8.6	9.8	8.5	8.1
9	10.2	16.5	13.5	17.4	5.8	-		9.6	9.6	10.3	8.7	8.0
10	12.2	15.6	15.2	17.6	8.2	1.6	(d) ~~●1,a,2,p~~	10.3	10.2	11.0	9.0	8.0
11	15.0	17.0	16.2	18.9	15.3	1.6	(e) ~~●a,1,a~~	11.1	11.2	11.8	14.3	13.1
12	17.2	15.0	11.7	17.8	11.6	7.2	(f) ~~●a,1,a~~	12.2	12.2	12.4	9.7	8.2

Table 6. Belogorka Station, June 1928

(a) Intermittent rain; cloud cover one-tenth ~~cloudy~~; barometer rising unsteadily.

(b) Intermittent rain.

(c) Hail; barometer rising, then falling.

(d) Intermittent rain; barometer rising, then steady.

(e) Intermittent rain; cloud cover one-tenth ~~cloudy~~; barometer rising, then falling.

(f) Intermittent rain; cloud cover one-tenth ~~cloudy~~; barometer rising, then falling; thunderstorm; no clouds.

Date	Air Temperature 0700	Air Temperature 1300	Air Temperature 2100	Max.	Min.	Precipitation	Weather Conditions	Soil 0.20 0700	Soil 0.20 1300	Soil 0.20 2100	Soil 0.40 0700	Soil 0.40 1300	Soil 0.40 2100	Soil 0.80 1300
20	8.2	9.4	9.2	12.5	8.0	1.6	(a)	11.0	12.0	11.7	11.5	11.4	11.6	10.5
21	9.2	12.3	10.3	13.5	8.1	0.0	(b)	10.6	12.3	12.3	11.0	10.9	12.7	10.3
22	11.4	14.2	11.2	15.5	8.9	17.5	(c)	11.7	14.4	13.7	11.2	11.3	12.0	10.3
23	11.7	13.5	11.0	17.5	8.9	3.2	(d)	12.2	13.4	15.0	11.8	11.7	12.4	10.4
24	12.7	14.8	12.8	15.7	6.1	0.5	(e)	12.5	14.1	15.0	12.2	12.0	12.6	10.8
25	12.0	17.0	12.4	17.5	6.4	-		12.4	16.3	15.8	12.3	17.3	13.3	10.8
26	13.0	18.3	13.8	19.5	8.1	-		13.0	16.3	16.0	12.9	12.8	13.6	11.2
27	14.1	20.5	15.1	22.1	8.5	0.0	(f)	13.2	17.1	17.5	13.0	13.0	14.0	11.4

Soil Temperatures for Indicated Depths (m)

Table 7. Belogorka Station, June 1928

(a) Intermittent rain; one-tenth ~~cloudy~~ cloud cover; barometer rising unsteadily.

(b) Intermittent rain; barometer rising, then falling.

(c) Intermittent rain; one-tenth ~~cloudy~~ cloud cover; barometer rising unsteadily.

(d) Intermittent rain; barometer rising, then falling.

(e) Intermittent rain; barometer rising, then falling.

(f) Intermittent rain.

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~~In reviewing~~ A review of these observations makes the temperature for the 0.40-meter depth at 2100 hours on 21 June look~~s~~ doubtful for two reasons:

1. The difference between the readings made at 2100 and 1300 is great, 1.8 degrees; ~~while~~ whereas the difference between the readings made at these hours on all other days does not exceed one degree.

2. This reading is greater than all three readings made on ~~that~~ the same day for the 0.20-meter depth. Consequently, the range in the daily variation for the 0.40-meter depth is greater than that for the 0.20-meter depth. It is obvious that the observer made a mistake, reading 12.7 degrees instead of 11.7 degrees.

Another error was made at 1300 hours on 25 June for the same depth. This figure must also be considered wrong for two reasons:

1. It exceeds the readings for the 0.20-meter depth not only on this day but on all preceding days and raises the variation range on this day to 5 degrees.

2. It completely changes the daily variation pattern, since on no previous day has the temperature risen during the period from morning to 1300 hours and the temperature has always been highest in the evening. Thus, there is an obvious error of 5 degrees.

The daily variation for different depths varies with the kind of soil. Soils with a small heat capacity (dry soils) can be expected to have high temperatures during the day and low temperatures during the night, that is, they have a wide daily variation range. Soils with a great heat capacity (wet soils) warm up and cool off to a lesser degree and more slowly and consequently have a narrower daily variation range. Good heat conductivity of the soil assures rapid transmission of heat downward while poor heat conductivity makes for such slow transmission of heat into the lower-lying layers of soil that ~~already~~ even at shallow depths there is considerable lagging

Air Temperature			Weather Conditions	Date	Temperatures for Indicated Depths (m)																				
					0.10			0.20			0.30			0.40			0.50			0.60			0.70		
0700	1300	2100			0700	1300	2100	0700	1300	2100	0700	1300	2100	0700	1300	2100	0700	1300	2100	0700	1300	2100	0700	1300	2100
				Granitic																					
				10 Oct	18.2	27.6	24.0	18.8	23.3	24.5	19.6	21.3	23.8	20.0	20.3	22.9	19.7	19.6	21.6	19.9	19.4	20.6	19.6	19.3	19.9
				11 Oct	17.1	26.0	23.9	18.2	22.5	24.5	19.5	20.7	23.9	20.2	20.0	23.0	20.5	19.6	21.7	20.4	19.6	20.7	20.1	19.6	20.0
				Sandy																					
16.4	22.4	16.1	Clear and quiet; light wind towards evening	10 Oct	15.0	21.5	20.0	15.8	17.8	19.6	16.3	16.2	18.0	15.8	15.5	16.0	14.7	14.6	14.6	14.0	14.0	14.1	-	-	-
				11 Oct	14.9	20.1	19.1	16.1	17.4	19.0	16.7	16.3	17.7	16.2	15.7	16.1	14.9	14.8	14.8	14.2	14.2	14.1	-	-	-
				Peaty meadow (wet) soil																					
				10 Oct	15.5	15.4	16.6	15.3	15.1	15.3	14.4	14.4	14.3	13.5	13.5	13.5	12.4	12.4	12.4	11.6	11.6	11.6	-	-	-
14.6	19.9	15.7	Clear and quiet	11 Oct	15.6	15.2	16.1	15.4	15.2	15.2	14.4	14.4	14.3	13.5	13.5	13.5	12.4	12.4	12.4	11.6	11.6	11.6	-	-	-

~~Figure~~ Table 8. Soil Temperature Observations in Different Soils

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in the warm~~-up~~ing and cooling~~-off~~ process~~es~~. Table 8 shows the soil temperature observations that were made simultaneously in three different areas having three different kinds of soil: granitic, sandy, and peaty meadow soils.

This example shows how different soils, under identical weather conditions, absorb heat in ~~a~~ varying ~~manner~~ degrees because of differences in their physical qualities.

Granitic soil warms up to the highest temperature because of its small heat capacity; ~~then comes~~ followed by sandy soil; and finally peaty soil which has great heat capacity because of the large amount of water in it. In rocky soil, which possesses good heat conductivity, daily temperature variations occur from the surface downward to a depth of more than 0.70 meter; in sandy soil, they are noted to a depth of 0.60 meter; but in peaty soil they are recorded only to a depth of 0.30 meter.

In rocky and sandy soils, the highest temperatures for the 0.10-meter depth were observed at 1300 hours, but for the 0.20-meter depth the highest temperatures occurred later, during the night.

Table 9 shows the daily temperature variation ranges occurring in the soils shown in Table 8. Table 9 ~~points out how the~~ indicates the dependence of temperature range~~s~~ ~~depend~~ on soil properties and how they ~~become~~ narrow~~er~~ with depth in the case of each kind of soil.

Soil Varieties	Depths (meters) 0.10	0.20	0.30	0.40	0.50	0.60	0.70
	Observations on 10 October						
Granitic	9.4	5.7	4.2	2.9	2.0	1.2	0.6
Sandy	6.5	3.8	1.8	0.5	0.1	0.1	-
Peaty	1.2	0.2	0.1	0.0	0.0	0.0	-
	Observations on 11 October						
Granitic	8.9	6.3	4.4	3.0	2.1	1.1	0.5
Sandy	5.2	2.9	1.4	0.5	0.1	0.1	-
Peaty	0.9	0.2	0.1	0.0	0.0	0.0	-

Table 9. Daily Temperature Variation Ranges in the Soils of Table 8

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Table 10. Annenkovo Station, 1927

Date	Air Temperature 0700	1300	2100	Max.	Min.	Precipitation	Weather Conditions	Soil Temperature for the 0.10-meter Depth: Draw-out Thermometers 0700	1300	2100	Savinov Thermometers 0700	1300	2100
							July						
1	15.1	23.2	16.0	24.0	12.3	-		17.1	29.2	21.7	17.7	24.9	25.1
2	15.9	19.9	17.1	21.7	13.4	-		17.0	27.7	21.9	18.5	22.6	24.1
3	15.0	23.0	18.4	24.0	10.3	2.2	● a, p, 3 + p (a)	18.6	27.7	20.6	18.7	24.7	21.8
4	16.7	19.1	17.9	22.0	14.3	1.4	● a, a, p (b)	18.2	20.0	19.4	18.5	19.4	20.4
5	18.1	20.5	20.7	25.0	14.9	1.5	● a (c)	19.4	24.0	22.7	18.0	24.1	24.4
6	19.1	24.0	20.9	28.0	11.8	-		20.4	28.3	24.9	18.9	26.1	25.8
7	19.7	27.0	18.0	28.2	13.2	6.2	K p (d)	22.6	31.7	21.0	20.6	27.0	23.0
8	19.3	25.5	22.9	26.0	[illegible].9	3.5	p; 3 ● K n (e)	19.4	26.8	23.2	19.3	23.4	24.2
July Average								19.4	26.2	21.7	19.3	24.2	23.6
							September						
1	12.5	15.1	7.6	18.5	7.5	-		17.6	19.8	14.6	20.0	21.5	19.2
2	7.5	10.9	8.9	11.5	4.9	0.0		12.0	15.0	13.3	15.9	17.0	16.4
3	7.7	12.1	6.4	14.5	5.9	-	● n (f)	11.5	15.9	12.8	14.2	15.5	16.1
4	8.5	14.1	8.3	15.5	3.3	-		11.8	19.8	14.2	13.0	17.9	17.7
5	10.9	17.7	12.9	19.3	5.9	0.0	● n (g)	14.3	21.3	15.7	14.0	19.0	18.0
6	10.7	15.7	6.9	16.8	6.8	-		13.5	22.1	14.1	15.5	19.5	17.2
7	6.7	10.7	8.1	11.5	2.9	-		11.2	15.4	12.6	13.9	16.4	15.2
8	7.9	14.9	12.5	17.5	4.2	0.1	● (h)	10.4	15.4	14.0	12.5	14.5	15.4
September Average								12.1	18.8	14.2	13.3	16.6	15.9

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(a) Intermittent rain; barometer rising, then falling.

(b) Intermittent rain; no clouds; barometer rising, then falling.

(c) Intermittent rain; barometer rising, then falling.

(d) Thunderstorm

(e) Lightning; intermittent rain, thunderstorm; no clouds.

(f) Intermittent rain; no clouds.

(g) Intermittent rain; no clouds.

(h) Intermittent rain; barometer rising, then falling.

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It is evident from Table 10 that in all instances the draw-out thermometers recorded greater rises and drops in temperature than the Savinov thermometers.

These differences in the readings of the two kinds of thermometers are reflected also in the average monthly figures. Since the warming ~~up~~ process during the summer months usually takes place in the morning and during the day, the temperature recorded by the draw-out thermometers at these times in July is higher than that recorded by the Savinov thermometers. In the evening when the temperature usually drops, the draw-out thermometers give lower readings than the Savinov thermometers.

In September, when morning temperatures are not so high, the draw-out thermometer shows lower readings than the Savinov thermometer; — a ~~this~~ fact also ~~is~~ reflected ~~also~~ in the average monthly figures.

Thus ~~then~~, the periodic variation, the daily variation, and the monthly variation are all different for the two kinds of thermometers. The daily variation range is greater for the draw-out thermometer.

The irregularity of the daily variation for the 0.20-meter depth at the Lugovodnaya station (July 1935), to be seen in Table 11, seems to explain why draw-out thermometers give higher readings during the morning, ~~and~~ particularly the daytime hours, and lower readings in the evening hours.

At this station, observations were made with Savinov thermometers for the shallower depths up to 0.15 meter and with draw-out thermometers for the depths from 0.20 meter downward. As is evident from the table, the soil possesses poor heat conductivity since the highest periodic temperatures occur in the evening even at ~~already for~~ the 0.10-meter depth. But for the 0.20-meter depth the highest periodic temperature occurs during the day rather than in the evening although the lag for this depth should be greater. Obviously, then, heat is transmitted

Date	Air Temperature					Precipitation	Weather Conditions
	0700	1300	2100	Max.	Min.		
1	14.3	15.9	8.4	17.1	1.1	-	
2	12.2	15.3	8.6	16.0	0.6	2.1	● p
3	11.4	13.7	8.6	15.2	4.7	0.1	●°2
4	11.2	13.4	9.6	18.7	0.1	2.2	● a
5	10.8	11.7	12.1	14.3	5.7	6.3	● a,n

Date	Savinov Thermometers									Draw-out Thermometers					
	0.05 m			0.10 m			0.15 m			0.20 m			0.50 m		
	0700	1300	2100	0700	1300	2100	0700	1300	2100	0700	1300	2100	0700	1300	2100
1	11.8	16.7	14.8	12.4	14.2	14.7	13.1	13.2	13.9	13.2	13.5	13.0	9.8	9.8	9.8
2	11.6	16.6	13.6	11.8	13.6	13.8	12.5	12.7	13.2	12.6	13.2	12.6	9.6	9.8	9.8
3	11.2	15.8	14.1	11.9	13.5	14.2	12.6	12.7	13.5	12.2	12.9	12.6	9.8	9.7	9.6
4	9.9	14.0	13.7	11.3	12.3	13.4	12.3	12.1	12.5	11.9	12.2	12.2	9.6	9.6	9.7
5	11.2	12.2	13.1	11.7	12.0	12.5	12.1	12.0	12.1	11.7	11.8	11.9	9.6	9.6	9.4

Table 11. Lugovodnaya Station, July 1935

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to the 0.20-meter depth directly along the thermometer case and raises the temperature at 1300 hours. This rise is not noted on 5 July which was a cold, cloudy day.

When draw-out thermometers are used for very shallow depths (0.03, 0.05, and 0.10 meter), the effect of the brass case may cause average annual temperatures to be somewhat inflated.

The Guide for Second-order Meteorological Stations (Fifth Edition) discourages the use of draw-out thermometers in brass cases for shallow depths (0.03, 0.05, 0.10, and 0.20 meter) because of the unreliability of results. This unreliability should be kept in mind when soil temperature observations of former years are processed.

Observations made at the Brasov Experimental Field Station in July 1928 (Table 12) show how observers may record incorrect readings.

Date	0.05-m Depth			0.10-m Depth			0.25-m Depth		
	0700	1300	2100	0700	1300	2100	0700	1300	2100
5	19.1	23.9	19.2	18.5	21.9	19.9	18.7	20.5	20.3
6	15.0	22.9	20.4	15.0	19.8	20.8	16.2	18.5	20.5
7	16.3	25.8	23.2	15.9	26.7	23.0	16.9	19.9	22.4
8	18.8	20.5	18.7	18.8	18.9	19.0	19.1	18.9	19.5
9	14.7	20.3	18.5	15.0	17.9	18.6	15.8	17.4	18.6

Table 12. Brasov Experimental Field Station, July 1928 (Savinov Thermometers)

In this table, the reading made for the 0.10-meter depth at 1300 hours on 7 July appears to be too high for the following reasons:

1. It is greater than the temperature recorded at the same hour for the preceding depth.

2. It considerably distorts the daily variation characteristic

of this depth in the given soil. On all other days, the temperature for this depth increases evenly from morning towards evening.

In order to decide which figure ought to be substituted for the reading made by the observer, it is necessary to compare the 1300-hour temperatures for this depth with the 1300-hour temperatures for the depths immediately above and below it.

The temperature for the 0.10-meter depth at 1300 hours must be lower than the 25.8 degrees recorded for the 0.05-meter depth and not less than the 19.9 degrees recorded for the 0.25-meter depth. In addition, it must be lower than the 2100-hour temperature.

In this manner, 21.7 degrees is found to be the reading which satisfies all the required conditions. The observer, therefore, made a 5-degree error in recording the reading as 26.7 degrees.

Observations made at the Stalingrad station in 1929 (Table 13) similarly illustrate how observers may record incorrect readings.

In this table, the temperature recorded for the 0.20-meter depth at 1300 hours on 1 September appears to be too low for the following reasons:

1. While this day was the warmest of all the days shown for the 0.10-meter depth both in regard to air temperature and in regard to soil temperature, ~~for the 0.10-meter depth~~ the temperature shown at 1300 hours for the 0.20-meter depth is lower than the temperatures at this time on the other less warm days.

2. The air temperature variation on 1 September was very similar to that of the preceding day; the temperature was merely two degrees higher. Similarly, the soil temperature variation for the 0.10-meter depth on 1 September was very similar to that of the preceding day; the temperature was merely 0.8 degree higher. Obviously, the soil temperature variations for the 0.20-meter depth on these successive days should likewise be similar. Accordingly, the reading for the 0.10-meter depth at 1300 hours on 1 September ~~for the 0.20-meter depth~~ ought to be several tenths of a degree greater than 28.1 degrees. Such a reading is

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Date	Air Temperature					Precipitation	Weather Conditions	Soil Temperatures for Indicated Depths (m):								
								0.10			0.20			0.40		
	0700	1300	2100	Max.	Min.			0700	1300	2100	0700	1300	2100	0700	1300	2100
29 Oct	17.7	26.1	22.2	27.5	14.8	-	-	23.3	29.8	28.6	24.6	27.5	28.3	27.4	26.9	27.1
30 Oct	19.8	27.4	22.1	28.1	16.6	-	-	24.1	29.7	28.5	24.9	27.6	28.2	27.0	26.7	26.8
31 Oct	18.6	28.1	23.7	30.0	16.6	-	-	23.6	30.6	28.8	24.6	28.1	28.7	26.8	26.5	26.7
1 Nov	20.9	30.0	24.8	31.2	18.9	-	-	24.4	31.2	29.6	25.3	25.6	29.0	26.8	26.5	26.8
2 Nov	19.4	24.4	16.7	27.7	16.6	-	-	24.6	29.5	26.3	25.4	27.6	26.5	26.9	26.9	27.7

Table 13. Stalingrad Station, 1929

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28.6 degrees, which if accepted in place of 25.6 degrees would indicate that the observer made an error of three degrees.

Table 14 shows the effect on temperature readings of water in the ebonite tube when snow is melting in the spring.

Date	Air Temp.			Precipitation	Weather Conditions	Soil Temperatures at Indicated Depths (m):								
						0.10			0.25			0.50		
	0700	1300	2100			0700	1300	2100	0700	1300	2100	0700	1300	2100
26 Mar	-0.4	0.8	0.0	-	-	-0.8	-0.3	-0.7	-1.4	-1.0	-1.3	-2.2	-2.1	-2.0
27	-0.2	0.9	0.9	-	-	-0.6	-0.3	-0.6	-1.2	-1.1	-1.0	-1.9	-1.8	-1.7
28	0.4	2.0	-0.8	-	-	-0.4	-0.2	-0.6	-1.0	-0.9	-1.0	-1.6	-1.6	-1.6
29	-4.5	0.9	-0.4	-	-	-0.6	-0.4	-0.6	-0.9	-0.8	-0.8	-1.4	-1.3	-1.3
30	-5.3	-1.8	-4.0	-	-	-0.5	0.4	-0.9	-0.8	-0.7	-0.8	-1.2	-1.2	-1.2
31	-5.0	-0.8	-2.6	-	-	0.6	0.7	-0.5	-0.7	-0.6	-0.6	-1.1	-1.0	-1.0
1 Apr	-5.1	-0.1	-3.1	-	Water entered tube ~~for~~ 0.50-m depth	-0.2	0.1	-0.4	-0.1	0.0	-0.1	-0.9	-0.8	0.0
2	-3.4	3.0	1.0	2.2	-	-0.2	1.4	0.0	0.0	0.0	-0.2	0.0	0.0	0.0
3	0.2	0.6	-2.4	-	-	0.0	0.1	-0.2	-0.1	-0.1	-0.2	0.0	0.0	0.0
4	0.7	3.2	-0.6	-	-	0.0	1.6	-0.1	-0.2	0.0	-0.2	0.0	0.0	0.0
5	-0.2	4.8	1.2	-	-	0.1	0.6	0.0	-0.1	0.0	0.1	0.0	0.0	0.0
6	1.4	6.2	2.6	-	-	1.5	1.4	1.0	-0.1	0.1	0.0	0.0	0.0	0.0
7	0.4	6.7	4.4	-	-	0.1	2.8	2.4	-0.1	0.2	0.0	0.0	0.0	0.0
8	5.0	1.0	-5.6	5.8	~~* e,2,p,3~~ (a)	1.2	1.5	0.1	0.1	0.1	-0.1	0.0	0.0	0.0
9	-6.0	-2.4	-1.3	1.8	~~* n,1,a~~ (b)	0.1	0.2	0.0	-0.1	0.0	-0.1	0.0	0.0	0.0
10	-1.0	0.0	-4.8	1.2	~~* e,p.~~ (c)	0.0	0.1	-0.2	0.0	0.0	-0.1	0.0	0.0	0.0
11	-2.0	0.6	-1.0	-	-	0.0	0.2	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
12	-1.7	3.4	1.3	6.1	~~● p,3~~ (d)	0.2	0.6	1.3	0.0	0.1	0.0	0.0	0.0	0.0
13	0.3	7.8	6.3	-	~~* n~~ (e)	0.5	2.9	3.4	0.0	0.3	0.2	0.0	0.0	0.0
14	3.5	10.8	4.6	-	Water removed from tube for 0.50-m depth	1.4	4.9	4.6	0.2	0.5	0.7	0.0	0.0	0.0
15	2.6	9.8	5.6	-	-	1.8	8.6	5.3	0.7	1.2	2.2	0.0	0.0	0.0
16	3.6	10.4	-	5.4	~~[illegible]~~ (f)	3.2	3.5	7.2	1.9	2.2	3.6	0.2	0.1	0.1
17	8.6	9.2	7.0	9.2	~~[illegible]~~ (g)	5.6	6.2	5.9	3.8	3.8	4.1	0.5	0.3	0.2

Table 14. Saratov Station, 1916

(a) Intermittent snow; barometer rising unsteadily.

(b) Intermittent snow; cloud cover ~~one-tenth clouds~~; barometer rising, then falling.

(c) Intermittent snow; barometer rising, then falling.

(d) Intermittent rain.

(e) Intermittent snow; no clouds.

(f) Intermittent rain; lightning.

(g) Intermittent rain; barometer rising unsteadily.

The table shows that the thermometer reading for the 0.50-meter depth at 2100 hours on 1 April jumped 0.8 degree and then remained at zero for 15 days. On 1 April, the observer noted on his table of observations that water had gotten into the thermometer tube. Because of the water, thermometer readings did not change until 14 April when the water was removed.

Correction of Individual Values and Interpolation

Errors discovered in observations for considerable depths, where daily temperature variations are small and where heat is transmitted very slowly, can in most cases be easily corrected by referring to the temperature variation in neighboring soil layers. It is considerably more difficult to detect errors in observations for shallow depths. Usually, only errors several degrees in magnitude can be detected and corrected. Errors may be corrected either by whole degrees or by tenths of a degree depending on the month and the depth for which an error in observation is discovered. During the winter months, temperature changes uniformly even for the shallow depths, and it is possible to detect and correct an error even though it is only tenths of a degree in magnitude. It is even more probable that corrections can be made by tenths of a degree for the greater depths where temperature variation is generally uniform.

Readings corrected during critical review must be marked with as asterisk to distinguish them from the readings accepted as reported by the observer.

When reviewing observations, it is important not only to correct obvious errors but also to fill in gaps in observations by means of interpolation. More precise monthly averages can be obtained when this has been done than when there are gaps in the observations.

It is usually not difficult to interpolate temperatures for the great depths. If the temperature for such depths changes very uniformly and undergoes a change of only 1-1.5 degrees during the entire month, it is possible to interpolate temperatures for as many as 25 days provided that thermometer readings have been made both at the beginning and end of the period for which interpolation is undertaken. Care must be exercised when interpolating for such a protracted period especially if the period is one when extreme temperatures set in.

When gaps are interpolated and errors corrected in observations for shallow depths, it is necessary to take into consideration the temperature variation for such depths on days when the weather was similar to that on the day being interpolated. Interpolation for shallow depths is possible during the winter months only when snow lies on the ground and when temperature for the shallow depths shows little change. Table 15 is an example of such interpolation for observations made at the Novozybkov Meteorological Station in December 1927.

In this table, there are four consecutive days for which observations for all depths are missing, but, due to the deep snow cover, temperature variation is uniform and interpolation is possible even for four consecutive days. If there are gaps of one day or of several consecutive days for all depths during the summer (when temperatures for the shallow depths change sharply) and if there are interpolated values in the basic weather observations of the table (the basic weather observations also being missing), interpolation for the shallow depths should not be undertaken for more than two consecutive days. When basic weather observations are complete, the number of permissible interpolations for shallow depths during the summer increases to three consecutive days and to four nonconsecutive days.

Date	Air Temperature 0700	1300	2100	Max.	Min.	Precipitation	Weather Conditions	Snow Cover	Soil Temperatures for Indicated Depths (m): 0.15 0700	0.15 1300	0.15 2100	0.20 0700	0.20 1300	0.20 2100	0.40 0700	0.40 1300	0.40 2100	0.80 1300
11	-11.1	-12.1	-18.8	- 9.0	-19.3	-		32	0.2	0.2	0.1	0.4	0.4	0.3	1.4	1.4	1.4	3.3
12	-22.1	-17.5	-20.1	-17.0	-23.3	-		32	-0.1	-0.2	-0.2	0.1	0.0	0.0	1.4	1.4	1.4	3.3
13	-16.4	-13.2	-11.3	-11.1	-21.3	0.1	(a)	32	-0.2	-0.2	-0.2	0.0	0.1	0.1	1.4	1.2	1.3	3.2
14	- 7.2	- 4.3	- 3.9	- 3.7	-11.3	0.8	(b)	32	-0.1	0.0	0.1	0.1	0.2	0.3	1.2	1.3	1.2	3.1
15	- 5.2	- 5.7	-13.2	- 3.0	-13.4	4.5	~~a.2,p.3; p.3~~ (c)	34	0.2	0.2	0.1	0.4	0.4	0.3	1.2	1.2	1.2	3.1
16	-10.3	- 7.5	- 7.8	- 7.5	-13.7	0.3	n.1,a.2,p.3 (d)	34	0.1	0.1	0.1	0.3	0.3	0.3	1.2	1.2	1.2	3.1
17	- 9.0	- 8.2	-10.3	- 7.6	-10.4	0.2	~~n.1,a.2,p~~ (e)	34	0.1	0.1	0.1	0.3	0.3	0.3	1.2	1.2	1.2	3.1
18	-11.3	-11.2	-11.0	-10.3	-11.6	-		*34	*0.1	*0.1	*0.1	*0.3	*0.3	*0.3	*1.2	*1.2	*1.2	*3.1
19	-12.8	-14.2	-16.2	-11.0	-16.4	-		*34	*0.1	*0.1	*0.1	*0.3	*0.3	*0.3	*1.2	*1.2	*1.2	*3.1
20	-17.9	-19.2	-21.8	-16.2	-22.1	-		*34	*0.1	*0.1	*0.1	*0.3	*0.3	*0.3	*1.2	*1.2	*1.2	*3.0
21	-19.7	-16.2	-13.2	-13.2	-23.8	-		*34	*0.1	*0.1	*0.1	*0.3	*0.3	*0.3	*1.2	*1.2	*1.2	*3.0
22	-12.2	- 8.1	- 9.2	- 7.7	-13.6	-		34	0.2	0.2	0.2	0.3	0.3	0.3	1.2	1.2	1.2	3.0
								34	0.2	0.2	0.2	0.3	0.3	0.3	1.2	1.2	1.2	3.0

Table 15. Novozybkov Agricultural Experimental Station, December 1927

(a) Intermittent snow; no clouds.

(b) Intermittent snow; barometer rising, then falling.

(c) Intermittent snow; barometer rising unsteadily.

(d) Slight snow storm; one-tenth ~~cloudy~~ cloud cover; barometer rising unsteadily.

(d) Slight snow storm; one-tenth ~~cloudy~~ cloud cover; barometer rising unsteadily.

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RESTRICTED

Ten-day averages containing interpolations for three days and monthly averages containing interpolations for four days are marked with an asterisk. If the number of gaps in observations exceeds four per month, interpolation is not carried out and monthly averages are not computed. But a greater number of days is permissible in the winter months.

An example of interpolation for shallow depths is shown in Table 16.

In this example, the observation for the 0.05-meter depth at 2100 hours on 27 July is missing. From the basic weather observations of the table, it is apparent that the air temperature dropped on 27 July and that there was a rainstorm towards evening. The drop in temperature is noticeable in the temperatures for the shallow depths. The following procedure is followed in finding the number to fill the gap occasioned by the missing observation.

1. The temperatures observed at 2100 hours and 1300 hours for the 0.05-meter depth are compared. It is seen that on the two preceding days they differed by 4 degrees and 4.7 degrees, but the differences became smaller on the succeeding days because of the colder weather.

2. The temperatures observed at 2100 hours for the 0.05-meter depth are compared with those observed at the same hour for the neighboring 0.10-meter depth. The comparison shows that these temperatures were equal on the preceding days but that the 0.10-meter depth temperatures were higher than the 0.05-meter depth temperatures on the colder succeeding days.

It is possible to assume from these comparisons that the most suitable number for the missing observation is 19.0 degrees. The number is marked with an asterisk to show that it was not obtained by observation.

Date	Air Temperature					Precipitation	Weather Conditions	Soil Temperatures for Indicated Depths (m):											
								0.05			0.10			0.20			0.40		
	0700	1300	2100	Max.	Min.			0700	1300	2100	0700	1300	2100	0700	1300	2100	0700	1300	2100
25	19.4	25.5	17.2	26.3	11.2	-		17.2	26.4	22.4	17.2	21.0	22.3	17.2	20.3	19.7	15.1	15.2	15.3
26	20.4	26.4	17.8	27.7	14.7	1.0	(a)	18.2	27.2	22.5	18.4	22.2	22.5	18.2	21.1	20.2	15.4	15.7	15.7
27	18.8	23.2	16.8	24.8	12.3	24.4	(b)	18.1	23.7	*19.0	18.3	20.9	20.0	18.4	19.3	18.8	15.8	15.8	15.8
28	11.5	14.9	9.6	16.7	9.7	15.2	(c)	15.3	15.7	15.0	17.3	16.5	16.5	17.9	16.5	16.2	15.7	15.6	15.3
29	12.8	17.6	10.9	19.5	8.4	2.3	(d)	12.7	17.5	16.5	13.6	16.7	17.2	14.9	15.6	16.2	15.0	14.9	14.8

Table 16. Aksenovskaya Station, July 1928

(a) Thunderstorm; intermittent rain.

(b) Thunderstorm; intermittent rain.

(c) Intermittent rain; less than one-tenth cloud~~y~~ cover; barometer rising, then falling; thunderstorm; barometer rising, then falling.

(d) Intermittent rain; thunderstorm.

After detailed analysis of monthly observations has been completed, critical review of the observations must be undertaken. It is still necessary to review extreme (maximum and minumum) soil temperature figures for each depth, the dates when they occurred, and for the winter months, also the number of days with zero and subzero temperatures, and the times when the first and last frosts occurred at each depth.

When reviewing these figures, it should be remembered that the transmission of soil temperature fluctuations into the soil slows up with depth so that the dates of occurrence of extreme temperatures usually advance with depth. But, conversely, extreme temperatures for greater depths sometimes occur before those for lesser depths. This happens when air temperature rises or falls repeatedly. If the first period is a protracted period, the temperature fluctuations peculiar to it have time to penetrate into the soil to a considerable depth whereas the temperature fluctuations of the following period, which are, even though brief, more severe, penetrate less deeply. Extreme temperatures will then result for the lesser depths from the later, but more severe, period than for the deeper depths from the earlier, but more protracted period. Thus it happens that maximum or minimum temperatures in a given month (as well as during the year) may occur earlier for the greater depths than for the lesser.

Because daily temperature variations do not reach down to depths of 1.6 meters and more and because these depths have only an annual temperature variation, the dates of occurrence of maximum ~~and minimum temperature variation, the dates of occurrence of maximum,~~ and minimum temperatures usually fall either at the beginning or at the end of a month except when the temperature, having reached its maximum sometime within a month, begins to fall or, having reached its minimum, begins to rise.

Since, in winter, temperature rises with increasing depth, the number of days with zero and subzero temperatures must decrease with depth. In spring, zero and subzero temperatures may be recorded in soil layers for which negative temperatures had previously not been observed.

Critical review of snow cover depth is carried out by comparing soil temperature observations with the observations from a stationary snow gauge (recorded in the table of basic weather observations). The characteristics of the place where the gauge and thermometers are set up are taken into consideration. Interpolation of snow cover depth figures and number of days with snow cover is undertaken only when the figures are perfectly obvious.

Conditions for Rejecting Observations

Low quality observations may be rejected either for the year as a whole or for individual months. They may be rejected in their entirety or with respect to individual depths. Observations may be rejected for the following reasons:

1. If thermometers are not set in accordance with instructions; for example, if drawer thermometers are set in metal tubes instead of ebonite; if the ground where thermometers are set is not natural, but deposited, etc. In such cases observations are rejected for the entire year or all years during which the incorrect setting of thermometers took place.

2. If the thermometer for any depth has a significant defect as a result of which it gives incorrect readings (especially, shifting of the scale or entrance of water into the ebonite tube). In this case observations are rejected either for the individual months during which the thermometer was defective, or for the entire year if it was defective during the entire year.

3. If thermometers in ebonite tubes set for very shallow depths (0.03 and 0.05 meter) give readings which are too unreliable and

which would distort the average annual temperature variation. Observations from such thermometers are not rejected for the entire year.

4. If observations for a given month contain a large number of gaps which cannot be interpolated. Such observations, however, are not rejected for the whole month. But if the number of gaps is great for all months of the year, the observations are rejected for the whole year.

5. If observations for a depth of less than 0.75 meter are made at only one hour daily instead of four (sic).

III. General Instructions Concerning Checking of Tables

It should be kept in mind that checking of tables is not a purely technical process but ~~that it~~ one which supplements critical review and that in all cases of doubt the checker should consult with the specialist who performed the critical review.

Only persons capable of making computations and fully familiar with critical review work ~~are~~ are to be permitted to act as checkers.

The readings of all thermometers not rejected by the specialist are checked. The fact that the observations have been passed by the specialist must be noted on the right side of a table.

All figures and all 10-day and monthly averages are checked. Also checked is that portion of tables which shows maximum and minimum temperatures, the dates of their occurrence, and the number of days with zero and subzero temperatures.

The depth of snow cover is checked day by day and by 10-day periods. Summaries and averages are verified.

IV. Preparing and Checking the Annual Summaries

General Information

In accordance with accepted procedure, annual summaries of soil

Temp.

Page 7 in original

JanFebMarAprMayJunJulAugSepOctNovDec

Figure 1. Annual Soil Temperature Variations, Ufa Station, 1928

Temp.

Page 11 in original

JanFebMarAprMayJunJulAugSepOctNovDec

Figure 2. Annual Soil Temperature Variations, Velikiy Ustyug Station, 1929

temperature observation tables are prepared by months and by 10-day periods. Information concerning snow cover depth is shown in connection with the summary by 10-day periods.

Preparing the Annual Summary by Months

The annual summary is prepared by listing the average monthly values for each depth according to observation periods. Then an average for the year is computed for each observation period [0700, 1300 and 2100 hours]. Finally, an annual average for each depth is computed from the observation period annual averages.

The monthly extreme (maximum and minimum) temperatures and the dates on which they occurred are listed in the following manner: if the extreme temperatures occurred on two days, both dates are listed; if they occurred over a period of more than two consecutive days and the number of days is odd, then the middle date is listed and enclosed in parentheses, but if the number of days is even, then the two middle dates of the period are listed and enclosed in parentheses.

Example: if the maximum temperature occurred on the days 5-9, the listing is (7); if the minimum occurred on the days 5-10, the listing is (7,8).

In cases when extreme temperatures occurred in several periods or on several individual days, then dates are listed only when there were not more than two of these; in all other cases, a dash replaces the date.

Example: if the maximum occurred on the days 7 and 18-20, the listing is 7(19); if on 14,16, and 17, it is -; if on 6,7, and 25-27, it is -; if on 7-11 and 18-20, it is (9,19).

Extreme temperatures for the year are chosen from these monthly listings as follows: if the extreme temperature occurred on two days or in two months, then only the months are listed, without dates. If there is a dash instead of a date in the monthly listing, then, in the year listing too, the month is followed by a dash.

The days with zero and subzero temperatures are totaled and the total is entered in the "Annual" column. The dates on which the first and last frosts occurred are also entered in their appropriate columns.

Preparing the Annual Summary by 10-Day Periods

Annual summaries by 10-day periods are prepared for depths up to 0.5 meter. In the summary, average values for each 10-day period are listed according to observation periods. Then an annual average is computed for each depth from this data. Extreme temperatures are also listed by 10-day periods.

In regard to depth of snow cover, the average depth for the 10-day periods is listed in round centimeters. If the depth is unknown, a dash is used to indicate this; if there was no snow cover, a zero is used.

After the annual summary has been prepared, it is subjected to checking according to the general rules for technical checking.

V. Critical Review of Annual Summaries

After technical checking, the annual summaries prepared from soil temperature observations are subjected to critical review.

The purpose of critical review of annual summaries is to give the observations a final qualitative rating in regard to their usefulness for practical and scientific purposes.

In the course of critical review of annual summaries, errors ~~defi-~~ of various kinds ~~can be exposed~~ which had ~~were~~ not previously been exposed or were not apparent during critical review of daily data can be located.

The person who makes the critical review of annual summaries must be acquainted with the physical and geographical conditions prevailing at the station and with the soil installations there; he must have all the notes which were made during preliminary and critical review of the monthly tables, the graphs of annual temperature variations for the various depths or isopleth graphs, the basic weather observational materials of the station being reviewed, and the annual summaries prepared from the soil temperature observations of neighboring stations.

The methods employed for critical review of annual summaries are the same as the methods used for reviewing daily data. In addition, it is useful to have observation data of preceding years available for comparison purposes.

The critical review of annual summaries should begin with a review of average annual temperatures for the various depths just as the review of monthly tables should begin with a review of average monthly values.

It should be remembered that average annual soil temperatures for the various depths differ merely by tenths of a degree (see Tables 1 and 2).

Average annual temperature varies uniformly with a change in depth, either decreasing with depth (insolation type) or increasing with depth (radiation type). Depending on climatic conditions in individual years, a prevalent type may change into the opposite type.

Observations made at the Novozybkov and Ufa stations (Tables 17 and 18) serve as examples of the change from the usual variation of average annual temperatures to the opposite variation.

Composition of Soil	Depth (m)	Average Annual Soil Temperatures					
		1925	1926	1927	1938	1929	1930
Clayey sand	0.15	8.6	8.6	9.1	7.6	8.2	8.3
	0.20	8.6	8.6	9.0	7.6	8.2	8.3
	0.40	8.4	8.4	8.8	7.6	8.0	8.3
	0.50	-	-	8.8	7.7	8.1	8.3
	0.60	8.4	8.4	8.7	7.8	8.1	8.4
Sand	0.80	-	-	8.5	7.7	8.0	8.3
	1.00	8.4	8.3	8.5	7.8	8.0	8.4
	2.00	8.4	8.2	8.4	-	-	-

Table ~~Figure~~ 17. Novozybkov Agricultural Experimental Station

Composition of Soil	Depth (m)	Average Annual Soil Temperatures					
		1924	1925	1926	1927	1928	1929
Chornozem	0.20	6.4	7.4	-	6.5	5.4	4.9
Red Clay	0.40	6.4	7.3	6.1	6.5	5.5	4.8
	0.80	6.6	7.2	6.3	6.6	5.9	4.9
Sand	1.60	6.6	7.0	6.2	6.4	6.1	5.1
	3.20	6.6	6.7	6.4	6.2	6.1	5.4

Table 18. Ufa Station

It is apparent from Table 17 that average annual temperatures at the Novozybkov station decrease with depth (insolation type), but that in 1928 and in 1930 they ~~have~~ experienced a converse variation (radiation type); 1928 was a cold year with very little snow cover during the winter, while 1930 was not cold but ~~also with~~ there was likewise little snow cover.

From Table 18 it is apparent that the radiation type is the usual type of temperature variation for the station. But in 1925 and 1927, the insolation type of variation was observed. There was deep snow cover in these years, and in 1925 the~~re was a~~ warm winter was as compared with the other years shown.

Often a station has a mixed type of variation, that is, with increasing depth the temperature first rises then drops, or the converse.

Examples:

Kuchuk-Totaykoy, 1915

Depth	0.10	0.20	0.40	0.80	1.60	3.20
Average Annual Temperature	11.5	11.7	11.8	11.9	11.8	11.7

Khonheutovskiy Sector, 1915

Depth	0.05	0.10	0.25	0.50	1.00	2.0	3.0
Average Annual Temperature	-	11.6	11.3	11.2	11.5	11.8	-

Gorodishchenskoye Forest, 1915

Depth	0.10	0.20	0.40	0.80	1.60	3.20
Average Annual Temperature	10.6	10.6	10.7	10.6	10.6	10.4

In reviewing the average monthly temperatures at the Velikiy Ustyug station in 1929 (see Table 3), the inaccuracy of the thermometer for the 0.50-meter depth is clearly apparent in each month during the whole year. In other cases, the average monthly temperatures do not give a sufficiently ~~yield an adequately~~ clear indication that the thermometer was inaccurate, but the average annual temperature does give an indication that some defect in the observations exists. Table 19 illustrates this fact.

Month	1925					1926				
	0.03	0.10	0.25	0.50	1.00	0.03	0.10	0.25	0.50	1.00
January	-4.7	-4.1	-3.5	-1.9	0.7	-3.2	-2.1	-0.6	-1.1	3.6
February	-2.9	-2.9	-2.3	-1.4	0.5	-4.5	-3.2	-1.8	-0.3	2.3
March	2.0	1.3	0.7	0.5	1.3	-1.3	-1.1	-0.7	-0.2	2.1
April	7.8	7.2	6.5	5.9	5.3	5.5	4.3	3.3	2.5	3.4
May	18.4	17.7	15.8	13.7	11.3	15.9	14.8	13.0	11.7	10.4
June	21.5	21.4	19.5	17.4	14.9	21.0	20.4	18.8	17.1	15.3
July	23.3	22.8	21.6	19.9	17.5	22.9	22.1	20.6	18.7	15.9
August	22.1	21.6	20.9	19.9	18.2	20.1	19.6	19.2	18.2	16.6
September	15.6	15.6	15.7	16.0	15.9	15.0	14.6	14.7	15.0	14.6
October	7.0	7.2	8.6	10.6	12.1	7.2	7.2	7.9	9.5	10.8
November	2.4	2.5	3.8	5.7	7.8	3.0	3.3	4.0	5.6	7.3
December	-0.5	0.0	1.1	2.8	5.0	-1.0	-0.6	0.4	2.3	4.4
Annual	9.3	9.2	9.0	9.1	9.2	8.4	8.3	8.3	8.4	8.9

Table 19. Average Monthly and Average Annual Soil Temperatures, Kostychevskaya Station

Note: The soil is sandy loam to a depth of 62 centimeters, clayey loam to a depth of 108 centimeters, and sand below 108 centimeters.

A ~~look~~ glance, first of all, at the average annual temperatures for both years discloses that the average annual temperature for the 1.00-meter depth in 1926 is high as compared with the temperatures for the neighboring depths, and stands 0.5-0.6 degree above them, while in 1925 it is more or less normal. A ~~look at~~ glance the average monthly temperature variations discloses that the temperature in the first half of 1926 for the 1.00-meter depth ~~are~~ is high. Reference to the notebooks and observation tables reveals the following note of the observer: "It was noticed on 12 July that the scale of the thermometer for the 1.00-meter depth is broken and has shifted downward. Comparison of this thermometer with its replacement showed that the former gave a 1.3-degree higher reading. When the new thermometer was ~~placed~~ put into the ebonite tube in place of the old, it showed within an hour a reading 1.2 degrees lower than the last reading of the old thermometer."

It is therefore definitely true that the thermometer gave readings which were too high during the first half of the year. If all readings during the year had been made with this thermometer, the average annual temperature would have been 1.2-1.3 degrees higher than it should have been; but since the defective thermometer was used only during the first half of the year (up to 13 July), the error was cut in half and only came to about 0.6 degree as the table indicates.

When did all readings of this thermometer become excessive? Reference to the daily observations for the 1.00-meter reveals that this thermometer began to give inexplicably high readings for this depth beginning with November 1925 and continuing through 1926. Apparently, the broken scale shifted downward slowly and by July was giving readings 1.2 degrees in error. Since the error in the readings during the first half of the year was not constant, it is not practicable to adjust them; all readings up to and including July must be rejected, but those from August on when the new thermometer was installed must be processed.

After review of average annual temperatures for all depths has been completed, detailed review of average monthly and annual data for all depths from observation period to observation period and from month to month is taken up. In making the detailed review, attention is ~~paid~~ given not only to the absolute values but also to the relationship between observation periods. Upon such comparison, the daily temperature variation for each layer and the rapidity of heat transmission downward into the soil become clear.

In the soil layers nearest the surface, the maximum temperature is observed at 1300 hours; with increasing depth, the maximum reading tends further and further towards 1900 hours until the daily temperature variation ceases entirely.

It is convenient to use graphs in connection with the analysis of periodic values by months and by 10-day periods just as it is convenient to use them in connection with the review of average annual temperatures. By studying the graphs, it is easy to discover defects in the observations.

The number of days with zero and subzero temperatures and the times of occurrence of the first and last frosts are ~~now~~ next reviewed. The number of days with zero and subzero temperatures must decline with increasing depth since, in winter, temperature rises with depth (but in spring it is possible to have a number of days with zero and subzero temperatures in the layers for which negative temperatures had ~~so far not~~ previously been observed). In all cases when irregularities in temperature variation are observed, it is necessary to refer to the review made of daily data, to air temperature, to temperature at the surface, to weather conditions, and sometimes even to the primary source, the observer's notebook.

Every question in regard to average data which has arisen during review of monthly tables is definitely settled during the review of annual summaries.

If in the course of the year an exchange of thermometers ~~took~~ has taken place, then the data for the month when the exchange took place should not be accepted in their entirety or should be marked with an asterisk as being doubtful. Average annual values should not be computed if there has been an exchange of thermometers ~~took place~~ during the year.

Average annual values in the summaries are marked with an asterisk if the data for four months periods is marked with an asterisk.

VI. Preparation for Printing

Copies are made of all summaries declared suitable for printing. After copies have been compared with the originals, the copies are submitted for printing.

The station must be properly identified on the summary. Identification includes the name of the station, its coordinates precise to one minute, the elevation of the station above sea level precise to round meters, and the initials and name of the observer.

All materials will be prepared according to stations in the same order in which they are to be printed, that is, from ~~N to S~~ north to south and ~~from W to E~~ west to east. Then two lists will be compiled in alphabetical order. The first list will include those stations ~~the~~ whose materials ~~of which~~ will be printed; the second list those stations ~~the~~ whose materials ~~of which~~ are available but will not be printed.

[Corrections of errors in the original-as indicated by an errata sheet have been made at the appropriate places in the translation]

\- END -